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Analysis of Grade XII Students' Mathematical Perceptions in Learning Colligative Properties of Solutions

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Abstract

Chemistry learning, especially in the subject of colligative properties of solutions, requires quantitative abilities and appropriate mathematical skills. Various studies show that difficulties in mathematics can hinder the understanding of abstract and calculation-based chemistry concepts. However, studies that specifically examine students' perceptions of mathematical ability challenges and their relationship to understanding the colligative properties of solutions are still limited. Therefore, this study aims to describe students' perceptions of mathematical ability and their understanding of the colligative properties of solutions, as well as to analyze the relationship between these two variables. This study uses a quantitative approach with a descriptive-correlational method. The research subjects consisted of 37 students of class XII C6 of State Senior High School 2 Tanjungpinang in the 2025/2026 academic year. Data were collected through a closed questionnaire using a five-point Likert scale consisting of 35 statements, covering the variables of perception of mathematical ability and understanding of the colligative properties of solutions. Data analysis was performed descriptively and using Pearson's correlation test with the help of IBM SPSS Statistics 24. The results showed that students' perceptions of mathematical ability were in the good to fair category, while their understanding of the colligative properties of solutions tended to be in the fair category. The Pearson correlation test produced a coefficient of r = 0.672 with a significance value of 0.000, indicating a strong positive and significant relationship between students' perception of mathematical ability and their understanding of the colligative properties of solutions. These findings emphasize the importance of strengthening students' abilities and confidence in mathematics to improve their understanding of quantitative chemistry concepts.

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INTRODUCTION

Chemistry learning is always related to the application of mathematics, especially in materials that require accuracy in calculation and quantitative analysis. One of the materials that is highly dependent on this ability is the colligative properties of solutions, which include vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure. To understand this material, not only is a mastery of theoretical concepts required, but also precision in using formulas and accurately interpreting calculation results (Gunawan et al., 2023).

Several studies show that mathematical ability is closely related to success in learning chemistry.

Anchen & Ying, (2022) found that students' achievements in mathematics play a major role in chemistry learning outcomes at the secondary level. Similar results were also reported by Maulim Silitonga et al., (2022) who stated that students with good mathematical abilities tend to get better results in learning chemistry than students with low mathematical abilities. At the university level, Lopez (2025) emphasized that mathematical ability is an important factor in improving the academic performance of chemical engineering students, especially in physical chemistry material covering thermodynamics and colligative properties.

In addition to influencing learning outcomes, mathematical understanding also plays an important role in the accuracy of calculations and increases students' confidence when solving numerically-based chemistry problems (McMillen et al., 2024). Cullen et al., (2021) shows that mathematical modeling is widely used in research on freezing point depression in the context of environmental chemistry. This shows that the function of mathematics in chemistry education is not only technical, but also strengthens conceptual understanding of quantitative chemical phenomena (Holme, 2019).

In terms of thinking skills, Kurniawan et al., (2025) state that mathematical thinking and reasoning skills have a significant impact on student learning outcomes and serve as an important foundation for developing logical and systematic thinking patterns. In line with this, Simorangkir & Rohaeti, (2025) reveal that logical thinking skills and confidence in mathematics greatly contribute to students' success in solving quantitative problems in chemistry. In the context of secondary school learning, Holme (2019) also emphasizes the importance of a systematic thinking approach to continuously combine mathematical and scientific concepts. This assertion is demonstrated by Musollini et al., (2026) through the use of mathematical models to predict the physical properties of solutions, which further underscores the importance of quantitative skills in understanding complex solution systems.

Although many studies have emphasized the importance of mathematical skills in chemistry learning, especially in quantitative material such as the colligative properties of solutions, empirical studies that directly examine students' perceptions of mathematical difficulties in this material are still quite limited. Most previous studies have focused more on learning outcomes or general understanding of chemistry concepts, without exploring how students interpret the calculation difficulties they encounter during the learning process (Anggraini et al., 2022). However, students' perceptions of their abilities and difficulties in mathematics can affect their confidence, problem-solving strategies, and engagement in chemistry learning.

Based on these shortcomings, the innovation in this study lies in mapping students' perceptions of mathematics in the context of chemistry learning and its relationship with the types of calculation errors related to the colligative properties of solutions. This study not only identifies challenges in calculation in general but also categorizes the types of mathematical errors made by students, such as errors in transferring variables, incorrect use of units, errors in manipulating formulas, and confusion in solving complex calculations, and relates them to students' anxiety levels when facing chemistry problems involving calculations.

Therefore, the purpose of this study is to describe the perceptions of students in class XII C6 at SMA Negeri 2 Tanjungpinang in the 2025/2026 academic year regarding the difficulties of mathematical calculations related to the material on the colligative properties of solutions. It is hoped that the results of this study can be used as a basis for teachers in developing chemistry lessons that are more integrated between understanding chemical concepts and strengthening students' mathematical skills.

METHOD

This study applied a quantitative approach using a descriptive-correlational method. This method was chosen to describe students' mathematical abilities and their understanding of colligative properties, as well as to analyze the relationship between the two variables.Tua et al., (2025) stated that a quantitative approach can be used to assess how well students understand the concept of colligative properties of solutions using numerical data analyzed through statistical techniques. In addition, the relationship between thinking skills or mathematical abilities and learning achievement in chemistry has been empirically proven. According to Pratiwi et al.,

(2024) In their research, the results of the analysis showed a significant positive relationship between students' formal thinking skills and their learning achievement in chemistry related to the material on colligative properties of solutions. Thus, the measurements in this study focused on how students perceive and evaluate their mathematical abilities and their understanding of chemistry concepts, which were then analyzed to obtain a comprehensive picture of the role of mathematical abilities in supporting the understanding of quantitative chemistry concepts. Overall, the research flow consisted of six stages, as shown in Figure 1.

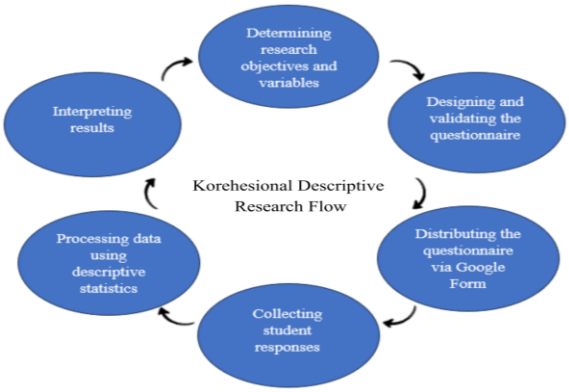

Figure 1. Research Flow of the Descriptive–Correlational Study

This research was conducted in class XII C6 at Tanjungpinang Senior High School 2 for the 2025/2026 academic year. Of the total 42 students, 37 students completed the questionnaire correctly and were used as respondents. The method used in this research was a closed- t questionnaire distributed via Google Form and consisting of 35 questions. Details of the statement items in the research instrument can be seen in Table 1 and Table 2 below.

Table 1. Statements Used as a Questionnaire of Variable X.

No	Variable X (Students' Perception Of Mathematical Ability)
1	I understand the meaning of moving variables to the other side of an equation
2	I understand that when moving terms, mathematical operations must be reversed
3	I often get confused when I see equations with many variables
4	I can change the form of a mathematical formula to find a specific variable
5	I often make calculation errors when solving chemistry problems
6	I can complete the calculations step by step without rushing
7	I easily lose track when calculations become lengthy
8	I can use units correctly in calculations
9	I am confident in my math skills in chemistry class
10	I often doubt whether my moves are correct
11	I feel anxious when doing chemistry calculations.
12	I find the calculations more difficult than the chemistry concepts.
13	I often forget to reverse the operation when moving segments
14	I once entered the wrong number into the formula because I was confused about the variables.
15	I often make mistakes when I have to change a formula into a derivative formula
16	A calculation error caused me to fail to answer the question about colligative properties.
17	I feel that my understanding of the concept is correct, but my calculations are still wrong.
18	I need additional practice specifically for the section on moving joints.

Table 2. Statements Used as a Questionnaire of Variable Y

No	Variable Y (Students' Understanding of Colligative Properties)
19	I understand what is meant by the colligative properties of solutions
20	I can explain the relationship between molality and freezing point depression
21	I understand why the vapor pressure of a solution is lower than that of a pure solvent.
22	I can explain the concept of osmotic pressure.
23	I can correctly use the formula $\Delta Tb = Kb \times m$
24	I can correctly use the formula $\Delta Tf = Kf \times m$
25	I can relate the mass of a solute to the number of moles
26	I can determine the variables sought in questions about colligative properties
27	I often get confused when deciding the first step in colligative properties problems
28	I often make mistakes in my calculations, even though I know the formula
29	I understand the concept better than the calculations.
30	I often get confused between the formulas for boiling point, freezing point, and osmotic pressure.
31	I often make mistakes when substituting values into formulas.
32	Difficulties with math caused my grades to be low.
33	I feel that my understanding is better without calculations.

No	Variable Y (Students' Understanding of Colligative Properties)
34	I need more explanation about the calculation steps
35	I feel that my learning outcomes could improve if I were more skilled at calculating.

In this study, there are two main variables used, namely Variable X and Variable Y, which are measured using a questionnaire. Variable X refers to students' perceptions of mathematical ability, including skills in algebra, accuracy in calculating, understanding of chemical formulas, and the ability to interpret numerical data in the context of chemistry learning. To measure this variable, there are 18 questions representing these various aspects.

Meanwhile, Variable Y refers to students' level of understanding of the colligative characteristics of solutions, which includes understanding basic concepts, the ability to understand the relationship between variables (such as mass, molality, number of particles, and changes in the physical properties of solutions), and the ability to apply these concepts in completing tasks. This variable is measured through 17 statement items. This questionnaire was created using a five-point Likert scale, and the assessment guidelines can be seen in Table 2.

Table 2. Assessment Guidelines for the Questionnaire on the Influence of the Ability to Transfer Parts in Mathematical Calculations on the Understanding of Colligative Properties

Criteria	Score
Strongly Agree	5
Agree	4
Undecided	3
Disagree	2
Strongly disagree	1

Source. (Memmedova & Ertuna, 2024)

Each questionnaire has two variables that will assess the effect of mathematical ability on the understanding of colligative properties of solutions, where these two variables are presented in Tables 3 and 4.

Table 3. Variable X Interval (Students' Perception of Mathematical Ability)

Interval	Category
76.6	Very Good
62.2 - 75.6	Good
47.8 - 61.2	Moderate
33.3 - 46.8	Low
18 - 32.4	Very Low

Variable X (students' perception of their mathematical ability) and Variable Y (understanding of the colligative properties of solutions) are each divided into five categories, determined based on the predetermined questionnaire score range. This classification aims to show the level of students' views before further statistical analysis is carried out.

Table 4. Interval of Variable Y (Students' Understanding of Colligative Properties)

Interval	Category
72.4	Very Good
58.8 - 71.4	Good
45.2 - 57.8	Moderate
31.6 - 44.2	Low
17 - 30.6	Very Low

From the results of this grouping, the relationship between Variable X (students' perceptions of mathematical ability) and Variable Y (students' understanding of the colligative properties of solutions) was analyzed using the Pearson correlation test (Pearson Product-Moment) processed through the IBM SPSS Statistics 24 program. This test serves to assess the direction and strength of the linear relationship between two variables that have an interval scale and meet statistical assumptions (Faradiba Jabnabillah & Nur Margina, 2022). The Pearson correlation coefficient (r) value ranges from 0.00 to 1.00, where the closer the value is to 1.00, the stronger the relationship, while a value closer to 0.00 indicates a weaker relationship or even no relationship at all (Azzahrah & Irmanda, 2024). The determination of the strength category of the relationship between the two variables is predetermined by Pearson correlation coefficient interval, as shown in Table X.

Table 5. Pearson correlation coefficient intervals

Interval	Category
0.81 – 1.00	Perfect Correlation
0.61 – 0.80	Strong Correlation
0.41 – 0.60	Moderate Correlation
0.21 – 0.40	Weak Correlation
0.00 – 0.20	No Correlation

RESULTS AND DISCUSSION

Analysis

This discussion is based on quantitative data analysis that has been processed descriptively and correlatively to assess the relationship between the variables studied. In chemistry

learning, the ability to think quantitatively is a crucial factor in understanding concepts involving calculations and mathematical relationships. Fan et al., (2025) state that quantitative reasoning skills in chemistry include the use of mathematical operations and logic to analyze and solve quantitative problems. These skills are critical because many concepts in chemistry, such as the colligative properties of solutions, require precision in calculations and the ability to think mathematically about the relationships between variables.

Table 6. Total Scores and Student Ability Categories for Variable X.

Students	TOTAL SCORES	Category
1	58	Moderate
2	64	Good
3	41	Low
4	51	Moderate
5	64	Good
6	66	Good
7	45	Low
8	44	Low
9	66	Good
10	72	Good
11	72	Good
12	54	Moderate
13	61	Moderate
14	53	Moderate
15	66	Good
16	68	Good
17	50	Moderate
18	41	Low
19	62	Good
20	69	Good
21	64	Good
22	68	Good
23	53	Moderate
24	57	Moderate
25	62	Good
26	68	Good
27	58	Moderate
28	64	Good
29	58	Moderate
30	55	Moderate
31	60	Moderate
32	61	Moderate
33	64	Good
34	64	Good
35	59	Moderate
36	60	Moderate
37	64	Good

Based on the results of the questionnaire on variable X regarding students' perceptions of their mathematical abilities, the distribution of responses shown in Table 7 indicates that the majority of students rated their mathematical abilities as Good, namely 18 students (49%). The dominance of this category indicates that, overall, students have a positive perception of their mathematical abilities, even though their confidence level has not yet reached the Very Good category.

Table 7. Frequency Distribution and Percentage of Student Ability Categories on Variable X

Category	Amount of students	%
Very Low	0	0
Good	18	49
Moderate	15	41
Low	4	11
Very Low	0	0

A total of 15 students (41%) were in the Fair category, indicating that there are still a large number of students who assess their mathematical abilities as being at an intermediate level. This shows that even though they have mastered the basics of mathematics, some of them still lack confidence and consistency in applying their mathematical abilities in the learning process. In addition, there were 4 students (11%) who fell into the Poor category, indicating that there was a group of students who faced challenges in mathematics and had the potential to encounter difficulties in learning that required quantitative analysis. The distribution of this data illustrates that perceptions of students' mathematical abilities were predominantly in the moderate to good categories, with the main tendency being in the Good category. This condition shows that, in general, students feel sufficiently capable of performing mathematical calculations, but their confidence levels have not developed to the maximum extent necessary to reach the Very Good category. No students were detected in the Very Poor category, which also indicates that, in general, there are no extreme perceptual barriers related to students' mathematical abilities.

This finding is important because in the process of learning chemistry, especially related to the colligative properties of solutions, students are required to have quantitative thinking skills, accuracy in performing calculations, and an understanding of the mathematical relationships between variables. This is in line with the opinion expressed by Fan et al., (2025) who explain that quantitative reasoning in chemistry involves the

application of mathematical operations and logic to analyze and solve quantitative problems.

Upon closer inspection, there are still many students in the Fair and Poor categories. This shows that some students are not yet confident in their mathematical abilities. Meanwhile, many studies show that self-perception and academic motivation play an important role in supporting learning success. Liou et al., (2024) found that students who have a high motivation profile supported by self-concept, perceived usefulness, and intrinsic interest in mathematics and science tend to achieve better academic results.

In line with this, Street et al., (2024) revealed that mathematical self-confidence is closely and positively related to students' learning behavior and academic achievement. These findings reinforce the understanding that students who fall into the Fair and Poor categories in this study may face difficulties in following lessons that require in-depth quantitative processing.

Further empirical evidence is provided by Shone et al., (2024), who state that students' perceptions of mathematics and their confidence in this field have a positive and significant relationship with their learning outcomes in mathematics. Similar results were also found in STEM learning research by Oppong-Gyebi et al., (2023), which showed that confidence in mathematics has a direct influence on student learning performance.

Table 8. Total Scores and Student Ability Categories on Variable Y

Students	Total Scores	Category
1	60	Good
2	54	Moderate
3	39	Low
4	51	Moderate
5	46	Moderate
6	56	Moderate
7	40	Low
8	40	Low
9	64	Good
10	54	Moderate
11	59	Good
12	54	Moderate
13	46	Moderate
14	46	Moderate
15	61	Good
16	64	Good
17	50	Moderate
18	47	Moderate
19	47	Moderate
20	55	Moderate
21	57	Moderate
22	51	Moderate
23	46	Moderate
24	54	Moderate
25	61	Good
26	56	Moderate
27	57	Moderate
28	52	Moderate
29	50	Moderate
30	47	Moderate
31	52	Moderate
32	48	Moderate
33	51	Moderate
34	61	Good
35	53	Moderate
36	52	Moderate
37	50	Moderate

Table 9. Frequency Distribution and Percentage of Student Ability Categories on Variable Y

Category	Amount of students	%
Very Good	0	0
Good	7	19
Moderate	27	73
Low	3	8
Very Low	0	0

Based on the results of the questionnaire on variable Y regarding students' perceptions of the colligative properties of solutions, the distribution of respondents' answers in Table 9 shows that most students rated their mathematical abilities as Fair, namely 27 students (73%). The dominance of this category indicates that, overall, students already have basic mathematical abilities, but have not yet reached an optimal level of mastery to support chemistry learning, which requires quantitative understanding.

A total of 7 students (19%) were in the Good category, indicating that only a few students felt confident and capable of performing the mathematical calculations required in the learning process. On the other hand, there were 3 students (8%) who were in the Poor category, indicating that there was a group of students who faced difficulties in mathematical aspects. This situation shows that there are variations in ability within the class that can affect students' level of understanding of the numerical and conceptual material on the colligative properties of solutions. The absence of students in the Very Good or Very Poor categories (0%) shows that students' mathematical abilities, based on their perceptions, tend to be focused at an intermediate level and are not at either extreme.

These findings indicate that although many students have a good foundation in mathematics, they still need to hone and expand these skills in order to deepen their understanding of chemistry concepts. The dominance of the Fair category indicates that students are still not fully confident in their mathematical abilities, thus requiring a learning approach that can increase their confidence and mastery of concepts.

The results of this study are in line with the findings of Chen et al., (2024) which shows that self-confidence in mathematics serves as a key link in the learning process, especially in relation to how students use feedback and support from teachers. In other words, the way students view their mathematical abilities not only reflects their intellectual abilities but also influences their engagement in learning activities. This opinion is supported by Yang et al., (2024) Those who emphasize that self-confidence in mathematics is an important indicator of success in learning mathematics, so that students' self-confidence has a real impact on their learning outcomes.

Furthermore, the tendency for students' abilities to remain at an intermediate level can be understood because the development of self-confidence is not only influenced by academic aspects but also by learning experiences, observations of other people's successes, support from the surrounding environment, and the psychological state of students. As described in the source (Bjerke et al., 2026) These elements are very important in shaping students' self-confidence in mathematics and science subjects.

Thus, based on the results of this study, it can be concluded that students' mathematical abilities, as perceived by them, have not yet reached a level that fully supports effective learning about the colligative properties of solutions. Therefore, it is necessary to adopt a learning approach that not only emphasizes conceptual understanding but also strengthens students' self-confidence through meaningful learning experiences, guidance from teachers, and learning strategies that can encourage gradual success.

From the students' scores on variables X and Y, a correlation analysis was performed using IBM SPSS Statistics 24, yielding the results shown in Table 10. The discussion of the relationship between Variable X (students' perceptions of their mathematical calculation abilities) and Variable Y (students' understanding of the colligative properties of solutions) began with grouping the scores of both variables into five categories based on a predetermined questionnaire score scale. This grouping aims to provide an overview of the trends in students' mathematical perception and understanding of colligative concepts before conducting inferential statistical analysis.

Table 10. Results of Pearson's Correlation Test between Variables X and Y

Correlations

		X	Y
X	Pearson Correlation	1	.672**
	Sig. (2-tailed)		.000
	N	37	37
Y	Pearson Correlation	.672**	1
	Sig. (2-tailed)	.000	
	N	37	37

**. Correlation is significant at the 0.01 level (2-tailed).

After that, the relationship between the two variables was analyzed using Pearson's correlation test (Pearson Product-Moment) with IBM SPSS Statistics 24. This test aims to assess the direction and strength of the linear relationship between two variables on an interval scale that have met the necessary statistical assumptions (Faradiba Jabnabillah & Nur Margina, 2022). Overall, the Pearson correlation coefficient (r) value ranges from 0.00 to 1.00, where a value closer to 1.00 indicates a stronger relationship, while a value closer to 0.00 indicates a weaker relationship (Azzahrah & Irmanda, 2024).

Based on the analysis conducted, a correlation coefficient value of r = 0.672 was obtained with a significance level of Sig. (2-tailed) = 0.000 on a sample size of N = 37. Since the significance value is below 0.05, it can be concluded that there is a significant relationship between students' perceptions of their mathematical abilities and their understanding of the colligative properties of solutions.

Referring to the guidelines for indicating correlation coefficients, a value of r = 0.672 falls into the category of a strong relationship (0.61–0.80), indicating that the relationship between the two variables is positive and strong. In other words, the higher the students' perception of their mathematical ability, the better their understanding of the concept of colligative properties of solutions.

These findings have conceptual relevance because the material on colligative properties in solutions requires quantitative thinking skills and mathematical calculation skills, especially when solving problems related to freezing point depression, boiling point elevation, osmotic pressure, and vapor pressure depression. Habiddin & Nagol, (2023) emphasize the importance of mathematics in explaining chemical phenomena, as mathematical operations are the main tools for understanding chemical concepts quantitatively. Therefore, the results of this study support the opinion that a positive attitude toward mathematical ability plays an important role in understanding numerical chemical concepts.

In addition, the results of this study are in line with the findings of Lee et al., (2023), which indicates that mathematical ability can be used as a predictor to assess student success in chemistry courses and can even identify students who are likely to fail with a fairly high degree of accuracy. This reinforces the results of this study, which show that mathematical aspects, in this case, perceptions of mathematical ability, are closely related to the ability to understand chemistry concepts that require numerical processing.

Anchen & Ying, (2022) also identified a significant positive relationship between achievement in mathematics and chemistry learning outcomes, indicating that students with good mathematical skills usually perform better in chemistry learning. From a psychological perspective, Liou et al., (2024) revealed that students' beliefs and motivation toward mathematics and science are important elements that influence academic achievement. These findings support the results of this study, which show that students' perceptions of their mathematical skills not only reflect their intellectual abilities but also impact their mental readiness and confidence levels when dealing with quantitative chemistry material. Therefore, the findings of this study not only prove a statistically significant relationship but also emphasize that perceptions of mathematical skills are an important factor contributing to students' understanding of the colligative proper-ties of solutions.

CONCLUSION

Based on the research objectives, it can be concluded that students' perceptions of their mathematical abilities fall into the moderate to good category, while their understanding of the colligative properties of solutions is mostly in the moderate category. These results show that students already have sufficient basic mathematical abilities, but still need improvement in order to better understand colligative concepts, especially in chemistry lessons that require precision in quantitative calculations and analysis.

In addition, the analysis results show a significant and positive relationship between students' perceptions of their mathematical abilities and their understanding of the colligative properties of solutions. The more positive students' perceptions of their mathematical calculation abilities, the better their understanding of colligative concepts. Therefore, improving students' mathematical calculation skills and confidence is very important in chemistry learning, especially to improve their understanding of quantitative material.

RECOMMENDATION

The results of this study indicate that students' mathematical calculation skills strongly influence their ability to solve problems related to colligative properties. Therefore, educators are advised to strengthen mathematical reinforcement during chemistry instruction, especially in identifying variables, manipulating formulas, and performing numerical operations. This study also recommends providing structured exercises and guided problem-solving steps to help students determine the correct procedure and formula selection. Future researchers may develop diagnostic tests or learning media focused on improving mathematical competence in quantitative chemistry topics.

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